MEASUREMENT OF EXCITATION FUNCTIONS OF PROTON-INDUCED NUCLEAR REACTIONS ON ^{NAT}DY

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Background

Radionuclide ^{161}Tb (6.89 d) is a promising alternative to the established therapeutic ^{177}Lu. It emits low energy β^- particles with mean energy of 154 keV and maximum energy of 593 keV. Moreover, it provides more conversion and Auger electrons that may enhance its therapeutic efficacy compared to ^{177}Lu.

Terbium-161 is usually produced in nuclear reactors via neutron capture on highly enriched ^{160}Gd targets, followed by a β^- decay of short-lived ^{161}Gd (3.66 min). While the production in nuclear reactors is already well established, its potential production by charged particles accelerators has not been entirely investigated. In principle, there are two possible reactions leading to ^{161}Tb – ^{160}Gd(d,n) and ^{164}Dy(p,α). The excitation function of the latter has been measured only once on natural dysprosium target and the results were published in 2013. We decided to re-measure in detail proton-induced excitation functions on ^{nat}Dy for all the radionuclides detected in the target.

Methodology

The excitation functions were measured using the stacked foil technique on the cyclotron U-120M of the Czech Academy of Sciences in the energy interval of 7.1–36.0 MeV. After the irradiation, the stacks were immediately disassembled and foils repeatedly measured using off-line high resolution γ-ray spectrometry. Cross-sections and their uncertainties were calculated from the activities of each particular radionuclide and other measurement parameters.

Results and Discussion

The cross-sections for the nuclear reactions ^{nat}Dy(p,x)$^{159m+g}$Ho, ^{160m}Ho, ^{160g}Ho, $^{161m+g}$Ho, ^{162m}Ho, ^{162g}Ho, ^{155}Dy, $^{157m+g}$Dy, ^{159}Dy, ^{155}Tb, $^{156m+g}$Tb, ^{160}Tb, ^{161}Tb and ^{159}Gd in the energy range of 7.1–36.0 MeV were measured and compared with both the previously published experimental data and with the theoretical prediction of the nuclear reaction model code TALYS (library TENDL2019). Thick target yields were deduced from the experimental data. If possible, activities of the ground-state isomers were corrected for the contribution of the metastable isomeric nuclei.

Conclusion

We provided a detailed cross-section data for the nuclear reactions ^{nat}Dy(p,x)$^{159m+g}$Ho, ^{160m}Ho, ^{160g}Ho, $^{161m+g}$Ho, ^{162m}Ho, ^{162g}Ho, ^{155}Dy, $^{157m+g}$Dy, ^{159}Dy, ^{155}Tb, $^{156m+g}$Tb, ^{160}Tb, ^{161}Tb and ^{159}Gd covering the energy range of 7.1–36.0 MeV. The thick target yields based on the experimental data allow for calculation of both the ^{161}Tb activity and the content of major radionuclidic impurity, ^{160}Tb, in the target as a function of energy, bombardment and cooling times.

Key words: Excitation functions, cross-section, proton activation, stacked-foil technique, Tb-161, Tb-160